Original Article

Long-term results of non-valved Glaucoma drainage implant surgery and glaucoma drainage implant combined with trabeculectomy

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Purpose: The purpose was to investigate the efficacy and complications of nonvalved glaucoma drainage implant (GDI) surgery and GDI combined with trabeculectomy. **Subjects and Methods:** Serial Japanese patients who received GDI were retrospectively investigated. The survival rate of eyes was analyzed using the Kaplan-Meier method, defining death as: (1) Intraocular pressure (IOP) <6 mmHg, or ≥22 mmHg, and <20% reduction of preoperative IOP, (2) additional glaucoma surgery, (3) loss of light perception. Prognostic factors of age, sex, previous surgery, type of glaucoma, synechial closure, preoperative IOP, type of GDI (single-, double-plate Molteno, Baerveldt 350) and GDI combined with trabeculectomy were investigated employing proportional hazards analysis. **Results:** One hundred and twenty-four eyes of 109 patients aged 53.3 ± 7.8 years old were analyzed. Types of GDI were single-plate (15.3%), double-plate Molteno (71.8%), and Baerveldt 350 (12.9%). The results of survival rate analysis were 86.1, 71.1, 71.1, and 64.6% for 1, 3, 5, and 10 years respectively. Thirty-four eyes (27.4%) died because of uncontrolled IOP (19.4%), loss of light perception (5.6%), and additional glaucoma surgery (2.4%). Single-plate Molteno was the only risk factor for failure. Persistent unphysiological hypotony (0.8%) and bullous keratopathy (5.6%) were observed. **Conclusion:** Nonvalved GDI surgery and GDI combined with trabeculectomy using nonabsorbable tube ligature proved to be an excellent device for any type of glaucoma in Japanese patients. Hypotony and corneal endothelial loss are the most serious complication in the long-term results of our patients.

Key words: Combined trabeculectomy, glaucoma tube shunt surgery, long-term results

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In glaucoma drainage implant (GDI) surgery, aqueous humor is drained and excreted from anterior chamber to orbital tissue through a tube. The original method designed by Molteno in 1969 has been modified, and currently, the Molteno implant, Baerveldt tube, and Ahmed valve are mainly used.[1] There have been many reports on long-term (exceeding 3 years) outcomes of treatment using the nonvalved type of GDI in other countries.[2-6] However, to the best of our knowledge, there has been no report on long-term results of GDI in WAsian eyes exceeding 3 years. In this study, we analyzed survival, prognostic factors contributing to the surgical outcomes, and postoperative complications in patients who underwent nonvalved GDI surgery and GDI combined with trabeculectomy at our hospital, and compared the outcomes in Japan with those reported in other countries.

Subjects and Methods

The treatment course was retrospectively investigated in 124 eyes of 109 consecutive Japanese patients who underwent nonvalved GDI surgery and GDI combined with trabeculectomy in the Ophthalmology Department, Japanese Red Cross Medical Center, between June 1993 and June 2009 and could be followed for 1 year or longer after surgery. Defining states meeting one of the following conditions as death of the eye, survival analysis was performed employing the Kaplan-Meier method and Cox proportional hazards model: (1) The intraocular pressure (IOP) is below 5 or above 22 mmHg, or shows <20% reduction from the preoperative IOP, (2) necessity of oral acetazolamide mediation and/or additional glaucoma surgery, and (3) loss of light perception in visual acuity. Regarding predictors contributing to the surgical outcomes, the age, gender, past medical history of surgery, disease type, gonioscopic findings (the presence or absence of peripheral anterior synechia [PAS]), preoperative IOP, implant type (single/double-plate Molteno, Baerveldt 350), and combined trabeculectomy were subjected to proportional hazards analysis and the hazard ratios (HR) were calculated. Regarding the presence or absence of PAS, PAS indices ≥50% and ≤50% were regarded as presence and absence, respectively, and unclear gonioscopic findings due to a preoperatively poor corneal condition was defined as unclear. Since surgeries of the bilateral eyes and multiple surgeries of the same eye were included in the data, the generalized estimating equation model was employed for analysis. This study was performed after approval by the Clinical Study Ethics Committee of the Japanese Red Cross Medical Center.

Surgical procedure

- The plate was to be placed at the inferior temporal site as a rule [Fig. 1a and b]. A fornix-based conjunctival flap was prepared for about half of the circumference, and the episcleral tissue was dissected under sub-Tenon anesthesia
- Bridle suture was applied to the two rectus muscles adjacent to the surgical field when Baerveldt 350 and single-plate Molteno were used, and to the three rectus muscles when

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double-plate Molteno was used
- The plate was fixed to the sclera with 8-0 nylon at a site 8-10 mm from the limbus
- The tip of the tube was ligated with 7-0 nylon by 3-1-1 through [Fig 2] and inserted into anterior chamber. To insert the tube into the anterior chamber, the anterior chamber was perforated about 1.5 mm from the limbs with a 22G needle or 22G V-lance at an angle, and the tube was inserted through this hole using a viscoelastic material to make the tube penetrate at a site posterior to Schwalbe's line. In patients with PAS in the whole circumference due to neovascular glaucoma (NVG) or patients following penetrating keratoplasty, the tube was inserted through the ciliary sulcus [Fig. 3]
- An about 5-6 mm portion of the tube on the limbal side was covered with the donor sclera or an autologous scleral patch
- The conjunctiva was sutured with 8-0 polyglactin, and the viscoelastic material was removed by aspiration irrigation in cases it was used.

In eyes in which the preoperative IOP exceeded 40 mmHg despite being under max treatment and the visual field condition was severer than in the middle stage, trabeculectomy was additionally applied at the side of the tube to prevent intraocular hypertension immediately after surgery [Fig. 1a and b]. Regarding NVG due to central retinal vein occlusion (CRVO) and diabetic retinopathy, GDI surgery was performed after sufficient pan-retinal photocoagulation (PRP). However, in eyes with insufficient PRP in the periphery because of poor mydriasis, retino-cryopexy was applied to 2-3 rows of four circumference in the nearest peripheral retina during GDI surgery in all cases. All surgeries were performed by a single operator (TH).

Postoperative management

After surgery, dexamethasone and antibiotic eye drops were administered for about 1 month, and glaucoma eye drops or oral acetazolamide was added when the IOP exceeded 21 mmHg. When the IOP was higher than 21 mmHg after 4 weeks, the suture was released to open the tube using an argon laser in the single-step method [Fig. 3, inset]. When the pressure exceeded 21 mmHg before 4 weeks in cases simultaneously treated with trabeculectomy, laser suture lysis of the trabeculectomy flap was performed. From May 2000, anterior segment optical coherence tomography (AS-OCT) was employed in all eyes to see the tube-inserted site and all eyes with hypotony to detect cilio-choroidal detachment (CCD).

Results

Six patients (6 eyes) who we were unable to follow at our hospital were excluded within 1 year after surgery. The number of the subjects, disease type and GDI type are listed in Table 1. Trabeculectomy + MMC were combined in 5 eyes treated with single-plate Molteno, 43 with double-plate Molteno, and 3 with Baerveldt. The mean duration of follow-up was 3.5 ± 0.7 years (range: 1-16 years), and the mean preoperative IOP was 34.9 ± 19.1 mmHg. On survival rate analysis [Fig. 4], the 1-, 3-, 5-, and 10-year survival rates were 86.1, 71.1, 71.1, and 64.6%, respectively. The cause of eye death [Table 2] was related to the IOP (below 5 mmHg, above 22 mmHg, or < 20% reduction from the preoperative IOP) in 24 eyes, which was the most frequent cause, followed by NVG in 9 (diabetic retinopathy [DMR]: 6, CRVO: 2, familiar exudative

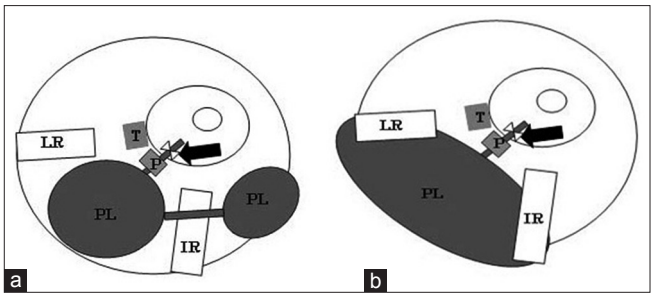

Figure 1: Schematic pictures of Molteno (a) and Baerveldt tube (b). When single-plate Molteno was applied to the right eye, the plate was placed between the lateral and inferior rectus (IR) muscles. When applying double-plate Molteno, the plates (P) were placed sandwiching the IR muscle (a). On applying a Baerveldt tube, the plate was inserted on the inferior temporal side (b). The tube tip was ligated with 7-0 nylon by 3-1-1 through (arrow). An insertion hole was prepared using a 22G V-lance at a site about 1.5 mm from the limbus on the scleral side, and the tube was covered with donor or autologous sclera (P). Combined trabeculectomy (T) was applied in the 9 o'clock direction, if necessary

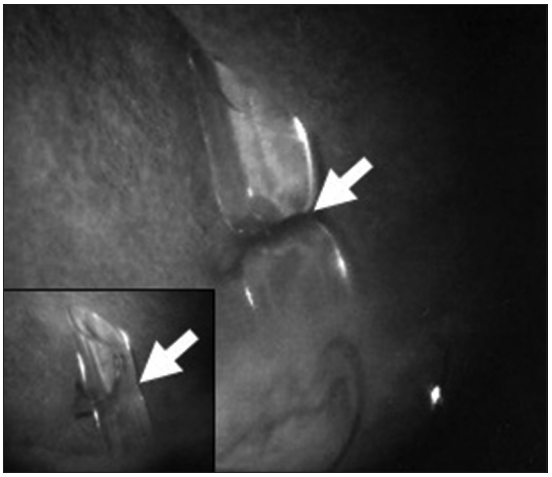

Figure 2: Tube ligation and release (inset). The tube tip was ligated with 7-0 nylon by 3-1-1 through. When the intraocular pressure exceeded 21 mmHg after more than 4 weeks, the suture was cut using an argon laser to open the tube [Figure 2, inset] (Patient No. 92)[15]

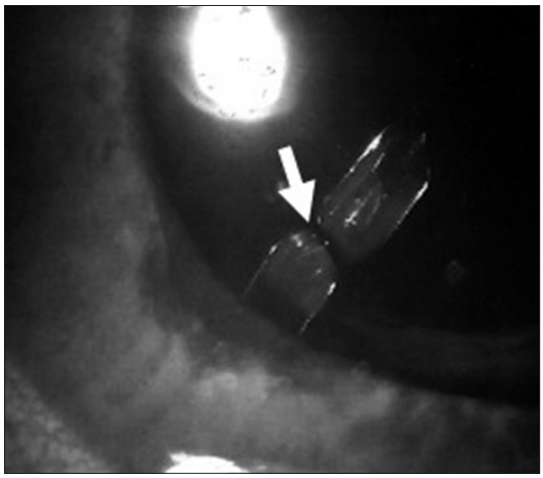

Figure 3: Tube insertion into the posterior chamber. In eyes with circumferential peripheral anterior synechia, the tube was inserted into the posterior chamber sulcus and positioned at a site at which the tube ligation could be cut by a laser. Arrow: Tube ligation site (Patient No. 94)

vitreo-retinopathy: 1), POAG in 5, SOAG in 8 (lens-induced glaucoma: 2, uveitis, corticosteroid glaucoma, postcorneal transplant surgery, postvitrectomy, others: 1 each), and SACG in 2. Additional glaucoma surgery was necessary in 3 eyes: 2 with NVG (all were DMR) and 1 with POAG. The visual acuity showed lost light perception in 7 eyes: 6 with NVG (DMR: 3, CRVO: 3) and 1 with uveitis-induced SOAG, with a total of 34 eyes 6 (27.4%). Regarding prognostic factors [Table 3] contributing to the surgical outcomes, the HR was high for the age, gender, past medical history of surgery, disease type, PAS finding, preoperative IOP, and combined trabeculectomy, but no significant difference was noted. However, regarding the GDI type, only the HR of Single-plate Molteno was significantly higher than that of double-plate [Table 3].

Table 1: Profile of patients

Age (mean±SD)	Gender (%)	Previous surgical interventions (%)	Diagnosis (%)
53.3±7.8 years old	Male: 72 (66.1)	TLE: 72 (58.1)	NVG: 51 (41.1)
Range: 13-92	Female: 37 (33.9)	VTX: 39 (31.5)	POAG: 28 (22.6)
		PEA+IOL: 39 (31.5)	SOAG: 36 (29.0)
		PKP: 5 (4.0)	SACG: 9 (7.3)
		RC: 19 (15.3)	

PAS (%)	Types of GDI, eyes (*) (%)
<50%: 62 (50)	Single-plate Molteno: 19 (15.3) (5*)
≥50%: 40 (32.3)	Double-plate Molteno: 89 (71.8) (43*)
Undetermined: 22 (17.7)	Baerveldt 350: 16 (12.9) (3*)

*Number of eyes with combined surgery of glaucoma drainage implant and trabeculectomy. SD=Standard deviation, GL=Glaucoma, NVG=Neovascular glaucoma, PAS=Peripheral anterior synechia, PEA+IOL=Phacoemulsification and intra-ocular implantation, PKP=Penetrating keratoplasty, POAG=Primary open angle glaucoma, RC=Retinal cryopexy, SACG=Secondary angle closure glaucoma, SOAG=Secondary open angle glaucoma, TLE=Trabeculectomy, VTX=Vitrectomy, GDI=Glaucoma drainage implant

Table 2: Eye death

Reason	Types of glaucoma (%)
Uncontrolled IOP	18 eyes (14.5): NVG 6, POAG 2, SOAG 8, SACG 2
Hypotony (IOP ≤6 mmHg)	6 eyes (4.8): NVG 3, POAG 3
Additional glaucoma surgery	3 eyes (2.4): NVG 3
Loss of light perception	7 eyes (5.6): NVG 6, SOAG 1
Total	34 eyes (27.4)

Uncontrolled IOP defined as >21 mmHg or IOP reduction <0%. NVG=Neovascular glaucoma, PAS=Peripheral anterior synechia, POAG=Primary open angle glaucoma, SACG=Secondary angle closure glaucoma, SOAG=Secondary open angle glaucoma, IOP=Intraocular pressure

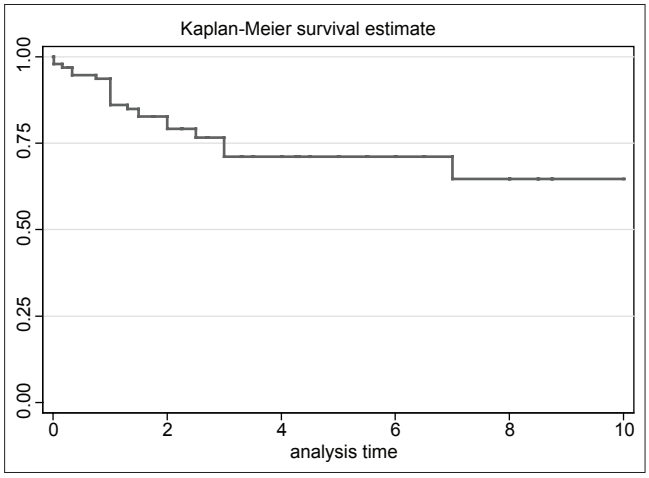

Figure 4: Kaplan–Meier survival estimate

Postoperative complications were classified into those which occurred within 1 month and more than 1 month after surgery as early and late complications, respectively. Early complications were a shallow anterior chamber in 13 eyes (10.5%), choroidal detachment in 10 (8.1%), anterior chamber hemorrhage in 9 (7.3%), conjunctival separation in 4 (3.2%), and an unfavorable tube position in 1 (0.8%), giving a total of 37 eyes (29.8%). The late complications were bullous keratopathy in 7 eyes (5.6%), an unfavorable tube position in 8 (6.5%), tube erosion in 7 (5.6%), phthisis in 2 (1.6%), persistent hypotony lower than 6 mmHg in 1 (0.8%), and endophthalmitis in 1 (0.8%), giving a total of 26 eyes (21.0%). The tube was re-inserted in all cases of an unfavorable tube position. Excluding 1 eye in which the tube was exposed because of rejection against donor scleral patch, all these were autologous scleral patch-applied cases. The IOP immediately after suture lysis of the tube transiently decreased to 6 mmHg in all cases and exceeded 10 mmHg within 4 weeks in most cases. A 6-9 mmHg IOP after laser suture lysis persisted for more than 6 months in 3 eyes (1 with NVG and 2 with POAG). Spontaneous remission was achieved after 14 months in 1 eye but the 6-9 mmHg pressure persisted for more than 5 years in the other 2 eyes. In one of these, macular edema and the appearance [Fig. 5a and b] and disappearance [Fig. 5c and d] of CCD, which can be observed only by AS-OCT, repeated. The tube has not been opened because of favorable IOP control after surgery in 3 cases (7.5, 2.1, and 2.0 years after surgery, respectively), in which 2 eyes were received combined trabeculectomy.

The corneal endothelial cell count decreased to <1,000/mm^2 in 14 eyes, and bullous keratopathy developed in 7 eyes. The period between the GDI surgery and bullous keratopathy ranged between 1 and 9 years. Of the 7 eyes of bullous keratopathy, the preoperative endothelial cell count was <1000/mm^2 in 2 eyes and bullous keratopathy developed in both cases. In the other 5 eyes, the preoperative count was between 1000 and 1500/mm^2 in 3 and more than 1500/mm^2 in 2 [Table 4]. In the former, 2 eyes were with Posner-Schlossman syndrome. One was with primary open angle glaucoma, but underwent 3 trabeculectomy surgeries before GDI surgery, and the corneal endothelial cell count was 1009/mm^2. In the latter, re-insertion of IOL was performed for dislocation of the ciliary sulcus-fixed lens in one. In the other, the plate capsule was removed due to an elevated IOP and the tube touched the cornea because of shallow anterior chamber.

Discussion

Based on the viewpoint of refractory glaucoma, generally, GDI surgery is judged as successful when the IOP decreases to 21 mmHg or lower and a more than 20% reduction from the

Table 3: Prognostic factors

	Simple analysis		Multivariate analysis*	
	Hazard ratio	95% CI	Hazard ratio	95% CI
Age	0.99	0.97-1.01	1.00	0.97-1.03
Male	1	1	1	1
Female	1.68	0.87-3.28	1.72	0.76-3.87
Presurgery				
TLE	0.97	0.49-1.92	1.42	0.63-3.22
VTX	1.00	0.49-2.05	1.05	0.43-2.60
PEA+IOL	1.14	0.57-2.30	1.27	0.50-3.23
PKP	0.45	0.31-5.00	1.45	0.26-8.01
RC	2.23	1.06-4.68	1.30	0.51-3.34
Types of GL				
NVG	1	1	1	1
POAG	0.82	0.37-1.85	0.97	0.33-2.83
SOAG	0.43	0.17-1.09	0.44	0.15-1.27
SACG	0.94	0.27-3.23	0.52	0.11-2.37
PAS				
<50%	1	1	1	1
≥50%	1.24	0.59-2.62	1.09	0.43-2.77
Unknown	1.63	0.66-3.99	1.20	0.43-3.39
Preoperative IOP	1.01	0.98-1.04	1.01	0.97-1.05
Types of GDI				
Double-plate	1	1	1	1
Single-plate	2.52	1.16-5.46	2.83	1.08-7.44
Baerveldt	1.56	0.45-5.39	2.05	0.50-8.35
Combined TLE				
No	1	-	1	-
Yes	0.44	0.20-0.94	0.56	0.21-1.5

IOP=Intraocular pressure, CI=Confidence interval, GDI=Glaucoma drainage implant, GL=Glaucoma, NVG=Neovascular glaucoma, PAS=Peripheral anterior synechia, PEA+IOL=Phacoemulsification and intraocular lens implantation, PKP=Penetrating keratoplasty, presurgery-previous surgery before initial glaucoma drainage implant surgery, POAG=Primary open angle glaucoma, RC=Retinal cryopexy, SACG=Secondary angle closure glaucoma, SOAG=Secondary open angle glaucoma, TLE=Trabeculectomy, VTX=Vitrectomy. *adjusted for age, sex, history of surgery, existence of peripheral anterior synechia, IOP, type of tube

preoperative IOP is achieved. In the literature, the success rate of nonvalved type GDI surgery was 52-100% at 3-10 years of follow-up.[2-5] Cataract extraction and Molteno implant insertion controlled the IOP at 21 mmHg or less with a probability of 1.00 (95% CI: 0.93-1.00) at 10 years or more after operation in eyes with cataract and POAG.[6] However, in the eyes, which included not only POAG but also secondary glaucoma, the success rates are 52% to 70.2%.[2-5] The success rate in the tube versus trabeculectomy study was the highest (70.2%), but this fact may be due to the exclusion of intractable cases, such as active rubeosis, iridocorneal endothelial (ICE) syndrome, aphakia, chronic or recurrent uveitis and eyes which exceeded more than 40 mmHg. Accordingly, the success rate in our study (71.1%) was relatively high compared to those at 5 years after GDI surgery in other studies, and this may have been related to the following two conditions: (1) Ischemia was thoroughly resolved by additionally applying PRP before surgery and retinal cryopexy during surgery in eyes with NVG, which is considered to be the most intractable. Previous studies clarified that the outcome of surgery for NVG was poorer than those of other diseases,[2] but no significant difference was noted in prognostic factors among the diseases in our patients, suggesting that treatment of NVG was successful. (2) For cases with a preoperative IOP exceeding 40 mmHg as well as middle stage or severer visual field impairment, trabeculectomy was concomitantly applied, which may have resolved the early ocular hypertension phase as well as contributed to long-term IOP reduction,[7-9] because combined trabeculectomy showed high HR in the simple analysis of prognostic factor.

The plate area may also be involved as a factor influencing the success rate of surgery. Heuer reported that the 2-year survival rates after single- and double-plate Molteno implant surgeries were 46% and 71%, respectively,[10] suggesting that this was due to the 2-times wider plate area of the double-plate (268 mm^2) than that (143 mm^2) of the single-plate Molteno implant. The recently reported ABC study also showed that the IOP reduction rate after 1 year was 2.2 mmHg lower in cases treated with Baerveldt than in those treated with Ahmed, and this was considered to be due to the wider plate area (Ahmed: 184 mm^2, Baerveldt: 350 mm^2).[11] In our patients, the HR of the single-plate was significantly higher than that of the double-plate in all three types of nonvalved GDI, confirming that the plate area markedly influenced the success rate.

We have employed the nonabsorbable suture method from the beginning of the introduction of GDI. In the original method reported in 1989, the tube tip was ligated with nonabsorbable 7-0 polypropylene and opened later by argon laser suture lysis to prevent postoperative hypotony after surgery using a Molteno implant.[12] A disadvantage of the method involving ligating the tube tip in the anterior chamber is the necessity of widening the hole in the sclera using a 22G needle instead of using 23G or V-lance when the tube is inserted into the anterior chamber because the region of the tube is thickened by ligation. Recently we have improved tube ligation from 3-1 to 1-3-1 through using 7-0 nylon, which enabled much easier insertion of the tube.

The cause of late intraocular hypotension persisting for a prolonged period after suture lysis is overfiltration. Stein *et al*. closely described the treatment of postoperative hypotony, in which revision surgery was necessary due to overfiltration at 140 days after surgery on average in 1.6% of all cases.[13] In our patients, 6 mmHg or lower late intraocular hypotension was observed in only 1 eye (0.8%). We performed intentional laser suture lysis only in cases with an IOP higher than 21 mmHg after 4 weeks. The tube was left closed in three patients because of favorable postoperative IOP control. The use of absorbable thread for tube ligation in these cases may lead to a high risk of hypotony after suture lysis of the tube. After suture lysis, 6-9 mmHg intraocular hypotension was observed for more than 6 months in 3 eyes and naturally remitted in 1 eye at 14 months. CCD may occur under this physiological intraocular hypotension, but, generally, it is not detectable by funduscopy, and detected only by AS-OCT [Fig. 5]. In these cases, hypotensive maculopathy may occur, and re-ligation of the tube should be considered when it persists for a prolonged period.

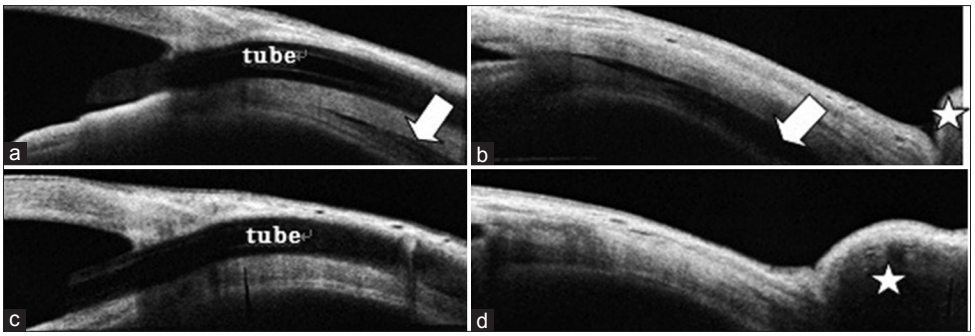

Figure 5: Anterior segment optical coherence tomography (OCT) photographs of tube and ciliary body. 6–14-mmHg intraocular pressure (IOP) variation persisted for 5 years after surgery. Cilio-choroidal detachment (CCD, a and b) was observed on anterior segment OCT when the IOP was 6-9 mmHg, and CCD disappeared when the pressure exceeded 10 mmHg (c and d). This CCD was not detectable by conventional funduscopy. The region marked with a star indicates a part of the Molteno Implant (Patient No. 75)

Table 4: Changes in the CEC in eyes with <1000/mm² after GDI surgery or eyes which developed bullous keratopathy after GDI surgery (colored column) (14 eyes)

Case number	Age, sex	Type of glaucoma	History of pre-GDI surgery	CEC/mm²*1	Combined surgery of GDI	History of post-GDI surgery	CEC/mm² (observation period, year)*2
2R	52, female	NVG	TLE	2262	TLE, RC	-	844 (11 years)
18	45, male	NVG	TLE, RC	3012	TLE, RC	-	710 (1-year)
27	41, male	VZV	TLE	3048	TLE	-	707 (7 years)
30	54, female	POAG	TLE	1009	TLE	-	942 (7 years)→UC
34	73, female	PS	TLE	1385	TLE	-	649 (6 years)
36	70, male	POAG	TLE	2568	-	EE, TR	UC (8 years)
38	43, male	PS	TLE	1869	TLE	-	933 (5 years)
39	70, male	PS	-	1309	-	-	UC (5 years)
43	69, female	SOG	RD, VTX	1763	TLE	-	791 (1.5 years)
44	52, male	PS	TLE, C	1062	TLE	-	UC (9 years)
53	78, male	ICE	TLE, C	759	TLE	-	UC (1-year)
65R	62, male	POAG	TLE	2118	TLE	-	904 (3.5 years)
100	64, male	CMV	TLE, C	998	-	-	UC (2 years)
109	43, male	ADG	TLO, C, RD, VTX	2352	TLE	re-IOL	UC (1-year)

*1 and 2: Before (*1) and after (*2) the glaucoma drainage implant surgery. ADG=Atopic dermatitis glaucoma, C=Cataract surgery, CMV=Secondary glaucoma due to cytomegalovirus infection, EE=Extraction of encapsulated tissue, GDI=Glaucoma drainage implant, ICC=Cytomegalovirus iridocyclitis, ICE=Irido-corneal endothelial syndrome, NVG=Neovascular glaucoma, POAG=Primary open angle glaucoma, PS=Posner-Schlossman syndrome, RC=Retinal cryopexy, RE-IOL=Re-IOL implantation because of IOL dislocation, RD=Retinal detachment surgery, SOG=Silicon oil glaucoma, TLE=Trabeculectomy, TLO=Trabeculotomy, TR=Tube repositioning because of corneal touch, CEC=Corneal endothelium count, VTX=Vitrectomy, UC=Uncountable, VZV=Secondary glaucoma due to varicella-zoster virus infection

In our patients, the incidence of bullous keratopathy was 5.6%, which is higher than those (about 1-2%) in other reports.[5,14] There may be two reasons for this. The first is that bullous keratopathy occurred in longer observation study. Mills and others reported corneal decompensation occurred in 10% after 44 months (range: 6-107 months).[2] In our study, the median period between the surgery and bullous keratopathy was 4.7 years (range: 1-9 years). The bullous keratopathy occurred more than 5 years after the surgery in 4 eyes out of 7 eyes [Table 4]. In addition to this, corneal endothelial loss is likely to occur as the course is followed for a prolonged period.[15] The second is that there were 4 eyes with ICE syndrome, Posner-Schlossman syndrome and *Cytomegalovirus* infection [Table 4], which are believed to cause endothelial damage. On the other hand, it is obvious that corneal endothelial loss from normal to <1000/mm² within a few years may be due to tube-corneal touch during GDI surgery or in the early postop period [Table 4]. Additional surgery after GDI also may have caused tube-corneal touch [Table 4]. In the eyes which had no reason for corneal endothelial loss as mentioned above, the angle of the tube against the cornea or tube inserting position may affect corneal endothelial loss in the long period after the surgery.

Summary

The outcomes of nonvalved GDI and GDI combined with trabeculectomy surgery in the long-term (3.5 ± 0.7 years, range: 1-16 years) are comparable or superior to those in other races. Hypotony and corneal endothelial damage are the most serious complications, which threaten visual acuity. Further investigation may be needed as for how to prevent corneal endothelial loss and hypotony after the release of tube ligation.

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